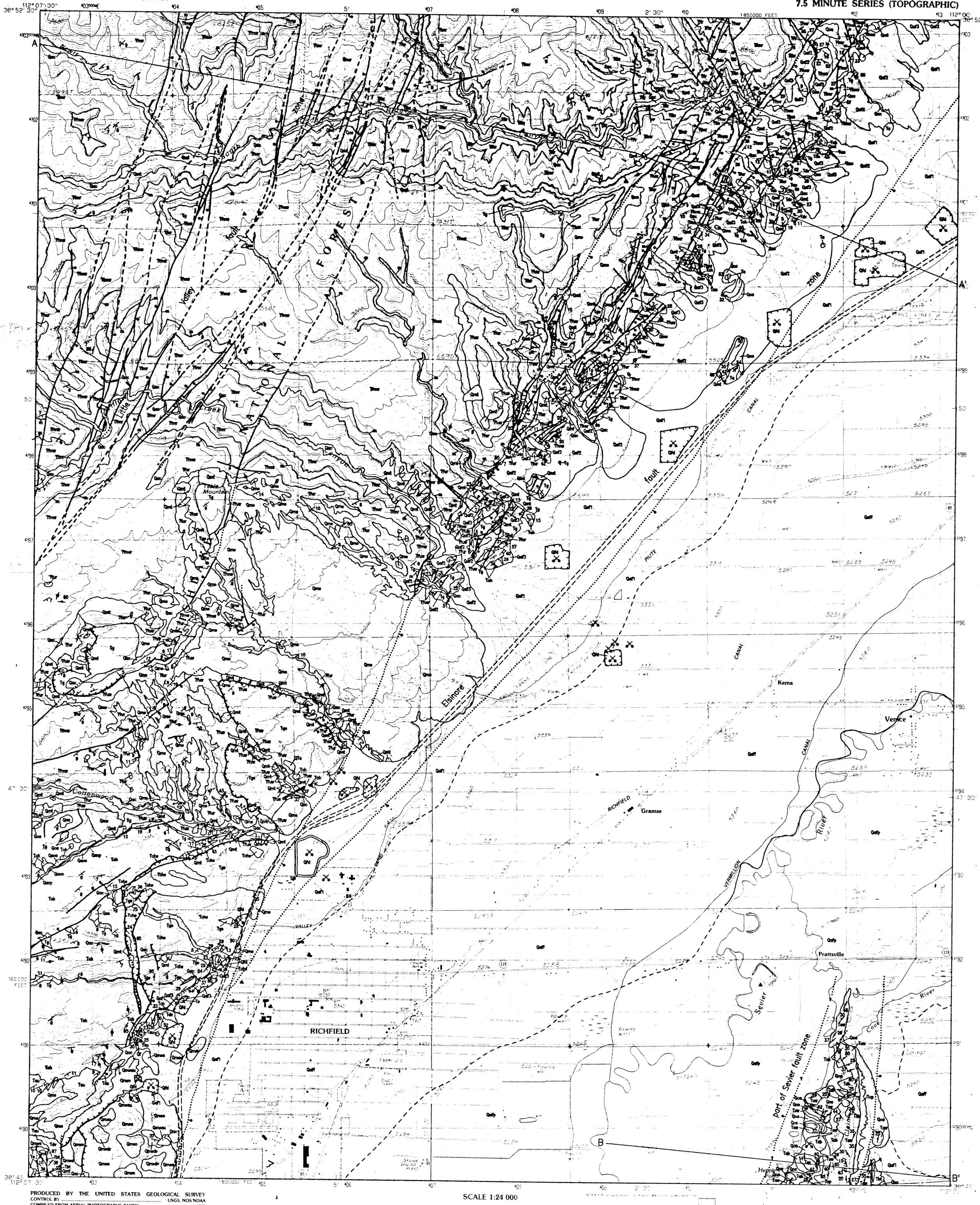
Plate 1

Utah Geological Survey
in cooperation with
U.S. Geological Survey

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

RICHFIELD QUADRANGLE
UTAH–SEVIER CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)



PRODUCED BY THE UNITED STATES GEOLOGICAL SURVEY
CONTROL BY ..... USGS, NOS/NOAA
COMPILED FROM AERIAL PHOTOGRAPHS TAKEN 1956
FIELD CHECKED 1961
LIMITED REVISION FROM AERIAL PHOTOGRAPHS TAKEN 1981
FIELD CHECKED ..... 1982 MAP EDITED 1986
PROJECTION ..... LAMBERT CONFORMAL CONIC
GRID: 1000-METER UNIVERSAL TRANSVERSE MERCATOR ..... ZONE 12
10,000-FOOT STATE GRID TICKS ..... UTAH, CENTRAL ZONE

SCALE 1:24 000

1 KILOMETERS 0 1 2
1000 METERS 0 1000 2000
1 MILES 0 1
1000 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10 000 FEET

CONTOUR INTERVAL 40 FEET
SUPPLEMENTAL CONTOUR INTERVAL 20 FEET

To convert meters to feet multiply by 3.2808
To convert feet to meters multiply by .3048

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U.S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225
OR RESTON, VIRGINIA 22092

UTAH
QUADRANGLE LOCATION

1 Mount Catherine
2 Beehive Peak
3 Aurora
4 White Pine Peak
5 Sigurd
6 Elsinore
7 Annabelle
8 Water Creek Canyon

ADJOINING 7.5 QUADRANGLE NAMES

field work in 1993-1994

Open-File Report 309

State Contract 94-1325
STATEMAP Agreement No. 1434-93-A-1175

Interim Geologic Map of the Richfield Quadrangle, Sevier County, Utah

by

Grant C. Willis
Utah Geological Survey

1994

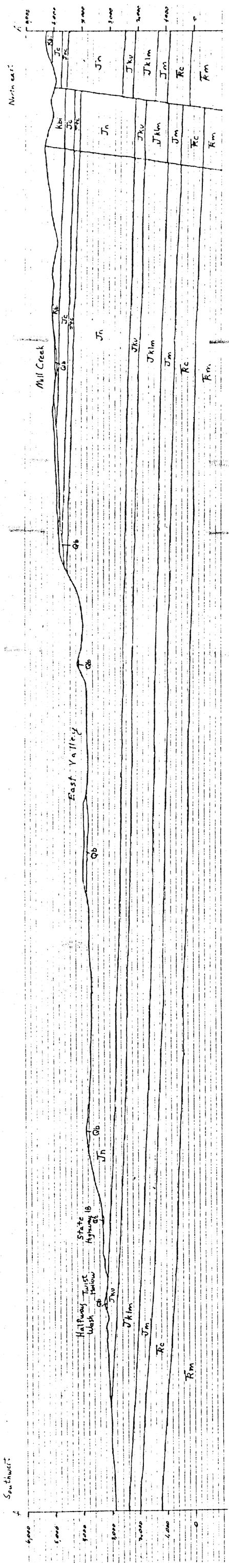
Utah Geological Survey
Department of Natural Resources
in cooperation with the
U.S. Geological Survey

Plate 2
Utah Geological Survey Open-File Map 324
Geologic Map of the Washington Quadrangle

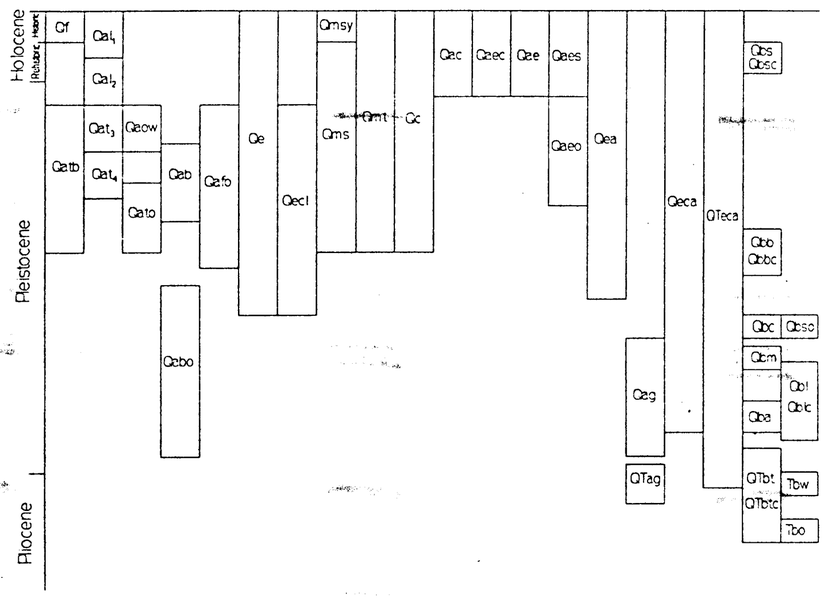
Interim Geologic Map of the Washington Quadrangle, Washington County, Utah

by
Grant C. Willis and Janice M. Higgins

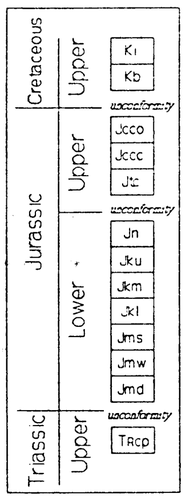
1995



Correlation of Surficial Deposits

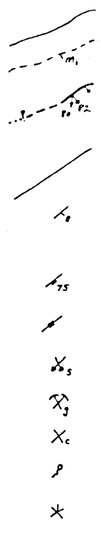


Correlation of Bedrock Units



Washington Quadrangle

Key to Map Symbols



Contact

Marker bed

High-angle fault – dashed where approximately located, dotted where concealed, queried where hypothetical; bar and ball on down-thrown side; dip of fault plane shown by thick arrow; rake of striations shown by thin arrrow

Prominent fracture

Strike and dip of inclined bedding

Strike and dip of joints

Inclined

Near-vertical

Pit – gravel or road fill (no letter), sand (s), cinders (c)

Quarry – gypsum (g), building stone (s)

Prospect – gypsum (g), cinders (c)

Spring

Volcanic vent

System	Series	Formation	Member	Symbol	Thickness feet(meters)	Lithology
Tert.-Quat.		Unconsolidated Deposits		-	0-100 (0-30)	
		Basalt Flows		-	0-150 (0-45)	
Cretaceous	Upper	Iron Springs Formation		Ki	400+ (122+)	
		bentonitic beds		Kb	55-85 (18-23)	
Jurassic	Middle	Carmel Formation	Crystal Cr. Mbr.	Jccc	0-50 (0-15)	
			Co-op Creek Member	Jcco	285 (87)	
		Temple Cap Formation		Jtc	200 (61)	
	Lower	Navajo Sandstone		Jn	2000 (610)	
		Kayenta Formation	Upper Member	Jku	380 (116)	
			Middle Member	Jkm	680 (207)	
			Lower Member	Jkl	110 (34)	
		Moenave Formation	Springdale Sandstone Mbr.	Jms	115 (35)	
			Whitmore Point Mbr.	Jmw	55(17)	
			Dinosaur Canyon Member	Jmd	250 (76)	
Triassic	Upper	Chinle Formation	Petrified Forest Mbr.	Trcp	300 (91)	

Description of Map Units

QUATERNARY

Qf **Artificial fill** -- Material emplaced for the contruction of dams and in landfills.

Alluvial Deposits

Qal$_1$ **Younger alluvial-stream deposits** -- Moderately to well-sorted silt, sand, and minor pebble-gravel in large active drainages; includes benches up to 20 feet (6 m) above current channels; 0-20 feet (0-6 m) thick.

Qal$_2$ **Older alluvial-stream deposits** -- Moderately to well-sorted silt, sand, and pebble-gravel deposits; dissected by channels incised up to 40 feet (12 m); mapped only in major drainages; 0-20 feet (0-6 m) thick.

Qatb **Boulder-terrace deposits** -- Poorly to moderately sorted mud- to large boulder-sized materials deposited in poorly developed terraces; clasts are mostly basalt; terraces are in several levels from 20 feet to 200 feet (6-60 m) above current drainages; mapped primarily near Mill Creek and Twist Hollow; 0-20 feet (0-6 m) thick.

Qat$_{3,4}$ **Stream-terrace deposits** -- Moderately sorted pebble to cobble gravel with some clay and sand deposits; partially cemented by pedogenic carbonate; well-rounded clasts; many clasts are exotic; subscripts denote relative ages and heights above the current drainage: level 3 are 40 to 90 feet (12-27 m) and level 4 are 90 to 140 feet (27-42 m); 0-20 feet (0-6 m) thick.

Qato **Older stream-terrace deposits** -- Moderately sorted pebble to cobble gravel with some clay and sand deposits; partially cemented by pedogenic carbonate; well-rounded clasts; many clasts are exotic; they are 120 to 200 (36-61 m) above major drainages; not correlative with the current drainages; 0-20 feet (0-6 m) thick.

Qafo **Older alluvial-fan deposits** -- Poorly sorted, basalt-boulder deposits with moderate amounts of fine-grained matrix; form alluvial fans and debris flows in Mill Hollow area; deposited at several levels up to 150 feet (46 m) above current drainages; higher levels have a thick pedogenic carbonate (caliche); 0-20 feet (0-6 m) thick.

Qaow **Older alluvial deposits** -- Moderately sorted, rounded, cobble- to small boulder-gravel that partially covers a broad sloping surface near Washington City; clasts are mostly basalt but a few percent are sedimentary and intrusive igneous clasts derived from near the Pine Valley Mountains; about 60 feet (18 m) above current drainages; 0-10 feet (0-3 m) thick.

Qab, Qabo
Boulder deposits -- Very poorly sorted, angular to sub-angular, boulder deposits with clasts up to 10 feet (3 m) in diameter; clasts are mostly from Upper Cretaceous and Tertiary formations and intrusive igneous rocks from the Pine Valley Mountains; deposits are eroded remnants of an apron of old alluvial-fan deposits on the flank of the Pine Valley Mountains; Qab deposits are 50 to 150 feet (15-45 m) above nearby drainages; older boulder deposits (Qabo) are 250 to 300 feet (76-91 m) above nearby drainages; but these drainages are not adjusted to regional base level; probably early to middle-late Pleistocene, but may be as old as Late Tertiary; up to 100 feet (30 m) thick.

Eolian Deposits

Qe **Eolian sand** -- Well- to very well-sorted, fine- to very fine-grained, well-rounded, frosted quartz sand; deposited in irregular hummocky mounds in depressions and on the lee side of ridges; locally forms poorly developed dunes; has thick pedogenic carbonate in most areas; 0-50 feet (0-15 m) thick.

Qecl **Eolian caliche and sand** -- Thick pedogenic carbonate (caliche) mixed with minor to moderate amounts of eolian sand (Qe); mapped in areas where most eolian sands have been stripped off, leaving the carbonate cap covering bedrock exposures; 0-20 feet (0-6 m) thick.

Mass-Movement Deposits

Qms, Qmsy
Landslide and slump deposits -- Very poorly sorted clay- to boulder-sized debris in chaotic, hummocky mounds; includes slump blocks in excess of 100 feet (30 m) across; basal detachments are developed on Petrified Forest Member in southern part of quadrangle and on Temple Cap Formation, Carmel Formation, and bentonitic beds in northern part; displace overlying bedrock formations, talus, and basalt flows; probably late Pleistocene to early Holocene; a small landslide in E 1/2, section 18, T. 41 S., R. 15 W. has historic movement (Qmsy); thickness highly variable.

Qmt **Talus deposits** -- Very poorly sorted, angular boulders with minor fine-grained interstitial materials; accumulated on and at the base of steep slopes; 0-20 feet (0-6 m) thick.

Colluvial Deposits

Qc **Colluvial deposits** -- Poorly sorted, angular to rounded, fine-grained to boulder-sized material deposited on moderate slopes; lacks well-defined drainage pattern; deposited by sheetwash, debris flow, and slope-creep processes; locally includes talus, eolian, or alluvial deposits; includes both active and dissected deposits; 0-30 feet (0-18 m) thick.

Mixed-Environment Deposits

Qac **Alluvial and colluvial deposits** -- Poorly to moderately sorted clay- to boulder-sized material in minor drainages; gradational with colluvial deposits; includes other deposits too small to map separately; 0-10 feet (0-3 m) thick.

Qae **Alluvial and eolian deposits** -- Moderately to well-sorted, clay- to sand-sized material deposited in broad, nearly flat areas; locally includes abundant eolian sand and minor gravel; minor to no pedogenic carbonate development; up to 50 feet (15 m) thick.

Qaes **Alluvial and eolian deposits of mostly sand** -- Similar to Qae deposits but consists mostly of sand; deposited in areas near thick eolian deposits; up to 50 feet (15 m) thick.

Qaeo **Older alluvial and eolian deposits** -- Similar to Qae but is deposited on older surfaces dissected by current drainages and has thick pedogenic carbonate; mapped in Washington and St. George areas; 0-30 feet (0-9 m) thick.

Qea **Eolian and alluvial deposits** -- Well-sorted eolian sand; locally reworked by alluvial processes and includes alluvial mud, sand, and gravel; has very thick pedogenic carbonate; deposited on old surfaces that have been protected from erosion for long periods and where eolian deposits can accumulate; 0-20 feet (0-6 m) thick.

Qeca **Eolian and alluvial deposits with thick carbonate soil on basalt flows** -- Eolian clay, silt, and sand, and alluvial gravel deposited on basalt flows; very thick pedogenic carbonate soil dominates unit; deposited in areas where streams flowed on top of flows; 0-20 feet (0-6 m) thick.

Basalt Flows and Related Deposits

Qbs, Qbsc
Santa Clara flow and cinder cone -- Dark-brownish-gray to black, subalkaline basalt flows (Qbs) and cinder cone (Qbsc); has small, abundant olivine phenocrysts in an aphanitic groundmass; flows have very jagged aa surface; cinder cones have youthful appearance; estimated 10,000-20,000 years old.

Qbb, Qbbc
Big Sand flow and cinder cone -- Dark-reddish-gray to dark-brownish-gray, quartz-bearing, basaltic trachyandesite; has large plagioclase and quartz, and small olivine phenocrysts; flow (Qbb) has abundant "rafts" of scoria; cinder cone (Qbbc) is well-formed and has thick pedogenic carbonate rind; age poorly constrained but estimated at 0.75 million years.

Qbc **Cedar Bench flow** -- Dark greenish-gray trachybasalt; has small olivine phenocrysts in an aphanitic groundmass; is very brittle and breaks with a conchoidal fracture; moderately jointed; four cooling units with combined thickness over 100 feet (30 m) in upper Black Gulch; south of Black Gulch is one thin unit 5 to 10 feet (1.5-3 m) thick on top of Middleton flow, locally with thin intervening gravel; K-Ar dated at 1.2±0.1 Ma (Best and others, 1980).

Qbm **Middleton flow** -- Moderate- to dark-gray to moderate-brownish-gray, quartz-bearing, basaltic trachyandesite; has large plagioclase (up to 0.4 inches, 1 cm) and quartz, and small olivine phenocrysts; consists of multiple flows of differing mineralogy separated by gravels in road cut near southern edge of quadrangle; main flow is probably sourced at Lava Ridge cinder cone; about 200 feet (60 m) above larger active drainages; K-Ar dated at 1.5±0.1 Ma (Best and others, 1980), which conflicts with calculated ages on other flows in area (see discussion in text).

Qba **Airport flow** -- Dark-greenish-gray to dark-brownish-gray trachybasalt; small olivine phenocrysts; as mapped may include parts of a quartz-bearing, basaltic trachyandesite flow; strongly jointed; weathering along fractures imparts a "patch-work" appearance; multiple cooling units exposed; about 330 feet (97 m) above larger active drainages; K-Ar dated at 1.07±0.04 Ma (Hamblin and others, 1981) but this date conflicts with calculated ages on other basalts (see discussion in text).

Qbso **Snow Canyon Overlook flow** -- Very dark-brown to brownish-black, trachybasalt with small phenocrysts of clinopyroxene and olivine; dense, brittle, and strongly jointed; age not determined but overlies Lava Ridge flow and is probably less than 1.5 million years old.

Qbl, Qblc
Lava Ridge flows and cinder cones -- Moderate- to dark-gray to moderate-brownish-gray, quartz-bearing, basaltic trachyandesite; has large plagioclase and quartz, and small olivine phenocrysts; consists of partially eroded cone (Qblc) and multiple flows and flow lobes (Qbl); several stacked flows are exposed in Black Gulch; age is poorly known, but is younger than Twin Peaks flows; the Middleton flow (dated at 1.5±0.1 Ma) may be from this source.

Qag **Alluvial gravel beneath basalt flows** -- Small isolated remnants of poorly to moderately sorted silt, sand, and gravel exposed beneath basalt flows; 0-50 feet (0-15 m) thick.

QUATERNARY-TERTIARY

QTbt, QTbtc
Twin Peaks flows and cinder cones -- Dark-gray to dark-brownish-gray, quartz-bearing, basaltic trachyandesite; has large plagioclase and quartz, and small olivine phenocrysts; moderately jointed; consists of extensively eroded cinder cones (QTbtc) and multiple flows (QTbt) at slightly different erosional levels; is older than Lava Ridge and Cedar Bench flows; cinder cones may be source of older remnants (Tbo) mapped in southern part of quadrangle and of West Airport Ridge flow (dated at 2.3±0.1 Ma and 2.24±0.11 Ma by Best and others, 1980; and Hamblin and others, 1981) in St. George quadrangle.

QTag **Alluvial gravel beneath basalt flows** -- Isolated boulder gravel beneath Twin Peaks flow; consists of boulders of Cretaceous and Tertiary sedimentary and igneous rocks derived from Pine Valley Mountains; 0-30 feet (0-9 m) thick.

TERTIARY

Tbw **Washington flow** -- Dark-greenish-gray tephrite basanite; has abundant small clinopyroxene and olivine phenocrysts in a seriate groundmass; dense; strongly jointed; caps ridge 360 feet (110 m) above the adjacent Virgin River; K-Ar dated at 1.7±0.1 Ma (Best and others, 1980).

Tbo **Older flows** -- Dark-gray to dark-brownish-gray, quartz-bearing, basaltic trachyandesite; large plagioclase and quartz, and small olivine phenocrysts; strongly jointed; consists of two main flow remnants 400 (120 m) and 660 feet (200 m) above current drainages; higher remnant is probably correlative with the West Black Ridge flow that was K-Ar dated at 2.3±0.1 Ma (Best and others, 1980) and 2.24±0.11 Ma (Hamblin and others, 1981); 20-80 feet (6-24 m) thick.

unconformity

CRETACEOUS

Ki **Iron Springs Formation** -- Yellowish-gray, brownish-gray, and yellowish-orange, fine- to coarse-grained sandstone and conglomeratic sandstone, interbedded with pale-reddish-gray, gray, and greenish-gray siltstone, mudstone, and fine-grained sandstone; mostly densely cemented but is locally friable; locally silicified; ledge and slope former; about 400 feet (120 m) preserved in quadrangle; complete thickness is 3,500 to 4,000 feet (1,070-1,220 m).

Kb **Bentonitic bed** -- Pale-gray to pinkish-gray, bentonitic clay and minor siltstone and fine-grained sandstone; nonresistant and poorly exposed; weathers to form soft "popcorn" soil; tentatively correlated with beds fission-track dated at 80.0±5 Ma (Hintze and others, 1994); 60 to 95 feet (18-23 m) thick.

unconformity

Jccc **Crystal Creek Member of the Carmel Formation** -- Reddish-brown, thin-bedded, poorly exposed sandstone and mudstone; exposed in only a few small outcrops beneath unconformity; 0 to 50 feet (0-15 m) thick.

Jcco **Co-op Creek Member of the Carmel Formation** -- Pale-gray, pale-greenish-gray, or pale-yellowish-gray, interbedded limestone, sandstone, and mudstone; fossiliferous; thin uniform bedding; 285 feet (87 m) thick.

unconformity

Jtc **Temple Cap Formation (Sinawava Member)** -- Dark-reddish-brown to pale-gray, slope-forming mudstone, claystone, and gypsum; contains three main beds of nodular gypsum 5 to 15 feet (1.5-4.5 m) thick; has thin volcanic ash beds with common biotite; 200 feet (61 m) thick.

unconformity

Jn **Navajo Sandstone** -- Pale-yellowish-gray to moderate-grayish-red, well-sorted, fine- to medium-grained quartz sandstone; grains are well-rounded and frosted; prominent eolian cross-beds; strongly jointed; about 2,000 feet (610 m) thick.

unconformity

JURASSIC

Jku **Upper member of the Kayenta Formation** -- Moderate- to dark-reddish-brown, fine-grained, thin-planar-bedded sandstone and mudstone in lower part; pale- to moderate-reddish-brown, thick-cross-bedded sandstone with planar bounding surfaces 1 to 5 feet (0.3-1.5 m) apart in upper part; upper part is entirely fine- to medium-grained, well-rounded, frosted quartz sand that resembles Navajo Sandstone except it has fluvial sedimentary structures; has three prominent marker beds labeled m$_1$, m$_2$; forms prominent ledges and cliffs; 380 feet (115 m) thick.

Jklm **Lower and middle members of the Kayenta Formation** -- shown on cross section only.

Jkm **Middle member of the Kayenta Formation** -- Interbedded reddish-brown siltstone, purplish-red to reddish-brown mudstone, and reddish-brown, fine-grained, calcareous, slightly mottled sandstone; punky gypsum in some intervals near the base; cross-cutting gypsum stringers are common; generally coarsens upward; forms slopes and small ledges; 680 feet (206 m) thick.

Jkl **Lower member of the Kayenta Formation** -- Pale-reddish-brown to moderate-reddish-brown, thin-bedded siltstone and very fine-grained, planar- to lenticular-bedded sandstone, interbedded with moderate-purplish-red mudstone; three interbeds of light-pinkish-gray to light-olive-gray dolomite, each about 6 inches (15 cm) thick, are present near the top; 110 feet (33 m) thick.

Jm **Moenave Formation, undivided** -- shown on cross section only.

Jms **Springdale Sandstone Member of the Moenave Formation** -- Pale-reddish-brown to grayish-yellow, fine- to medium-grained, cross-bedded sandstone with interbedded light-purplish-gray siltstone near the middle; weathers to rounded ledges; 115 feet (35 m) thick.

Jmw **Whitmore Point Member of the Moenave Formation** -- Greenish-gray claystone interbedded with pale-brown to pale-red, thin-bedded siltstone with several 2 to 6 inch (5-15 cm) thick beds of light-greenish-gray dolomitic limestone that contain algal structures and fossil fish scales; nonresistant and poorly exposed; about 55 feet (17 m) thick.

Jmd **Dinosaur Canyon Member of the Moenave Formation** -- Interbedded moderate-reddish-brown siltstone and pale-reddish-brown to grayish-red, fine-grained, thin-bedded sandstone with laminated cross-beds; poorly exposed; 250 feet (76 m) thick.

unconformity

TRIASSIC

TRc **Chinle Formation, undivided** -- shown on cross section only.

TRcp **Petrified Forest Member of the Chinle Formation** -- Light-brownish-gray to grayish-purple bentonitic shale and siltstone with several interbeds of pale-yellowish-brown, cross-bedded sandstone up to 10 feet (3 m) thick; petrified wood is common; clays weather to a "popcorn" surface; poorly exposed; 300 feet (215 m) exposed but is about 700 feet (91 m) thick.

TRm **Moenkopi Formation** -- shown on cross section only.